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(54) **HIGH EFFICIENCY DISTRIBUTED DEVICE-TO-DEVICE (D2D) CHANNEL ACCESS**

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(58) **Field of Classification Search**
None
See application file for complete search history.

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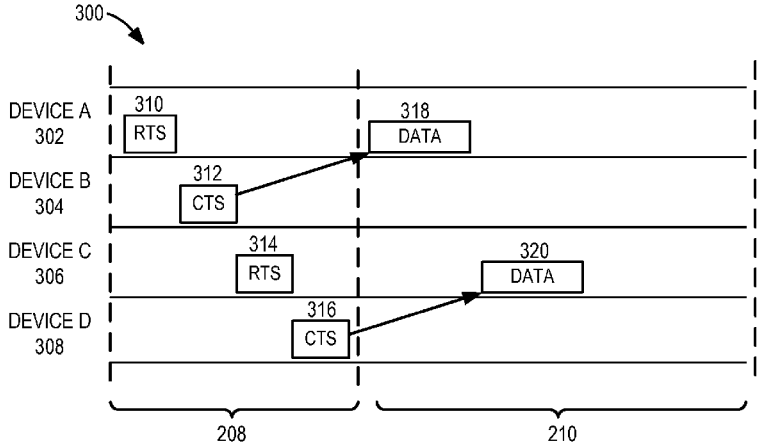
(57) **ABSTRACT**

Techniques for facilitating device-to-device (D2D) communications using a high efficiency distributed channel access scheme are generally described herein. In some examples, a communication zone allocated for wireless D2D communications is divided into resource contention and scheduled transmission portions. The resource contention segment may be used to transmit a request message from a transmitting device to a receiving device (a request-to-send message), and transmit a response to the request message from the receiving device to the transmitting device (a clear-to-send message). The response can indicate a time for the data transmission to occur during the scheduled transmission segment. During the scheduled transmission segment, the scheduled data transmission and other D2D data transmissions among the various devices will be performed. In further examples, contention access techniques may be used during the resource contention segment to manage access to the resource channel.

16 Claims, 7 Drawing Sheets



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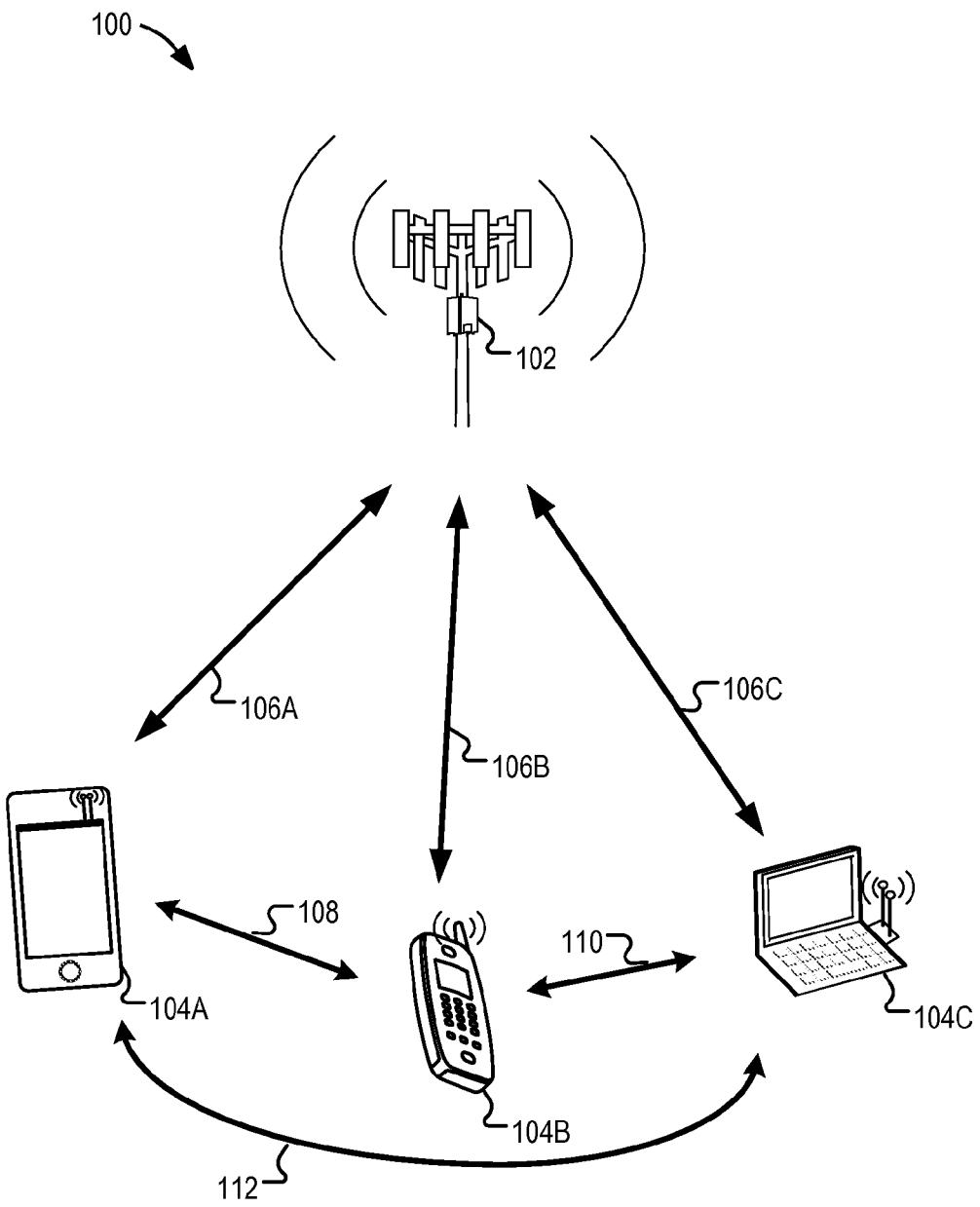

FIG. 1

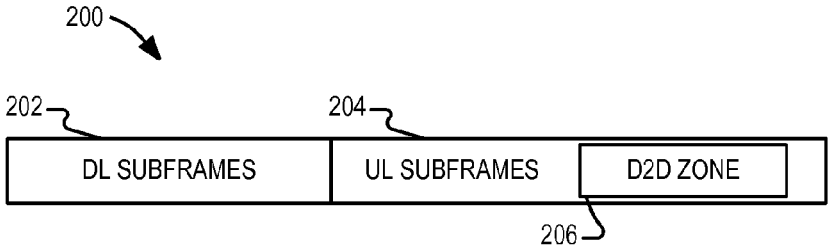

FIG. 2A

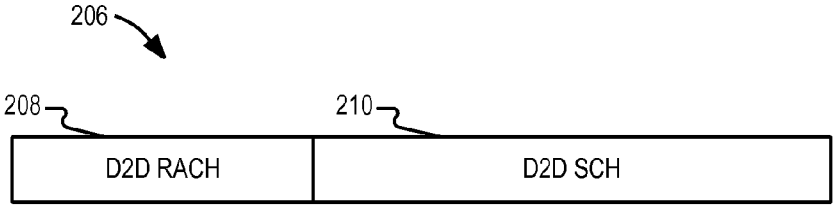

FIG. 2B

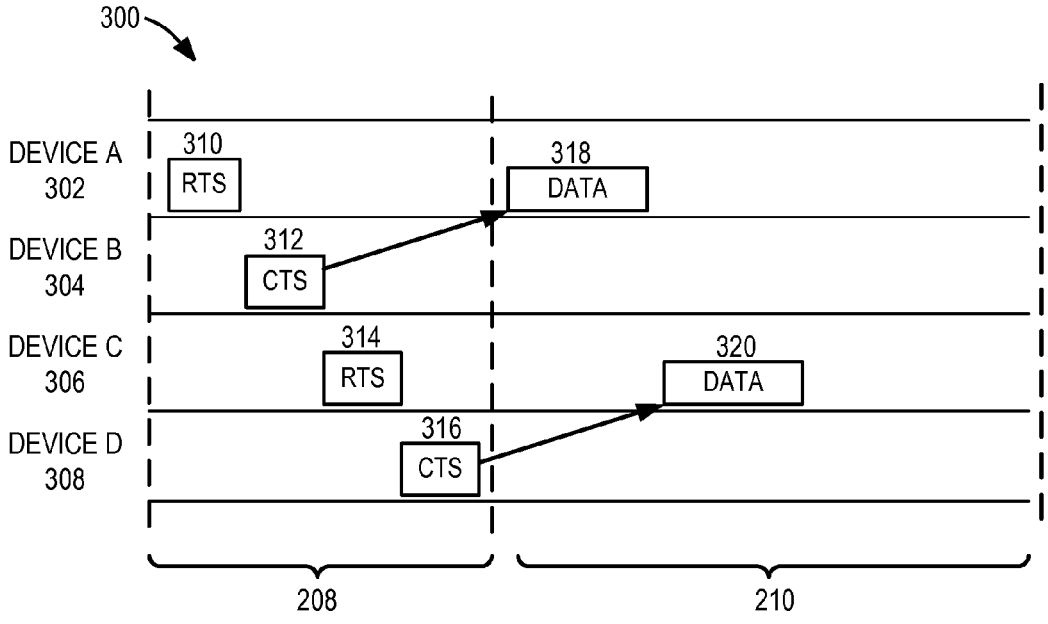

FIG. 3

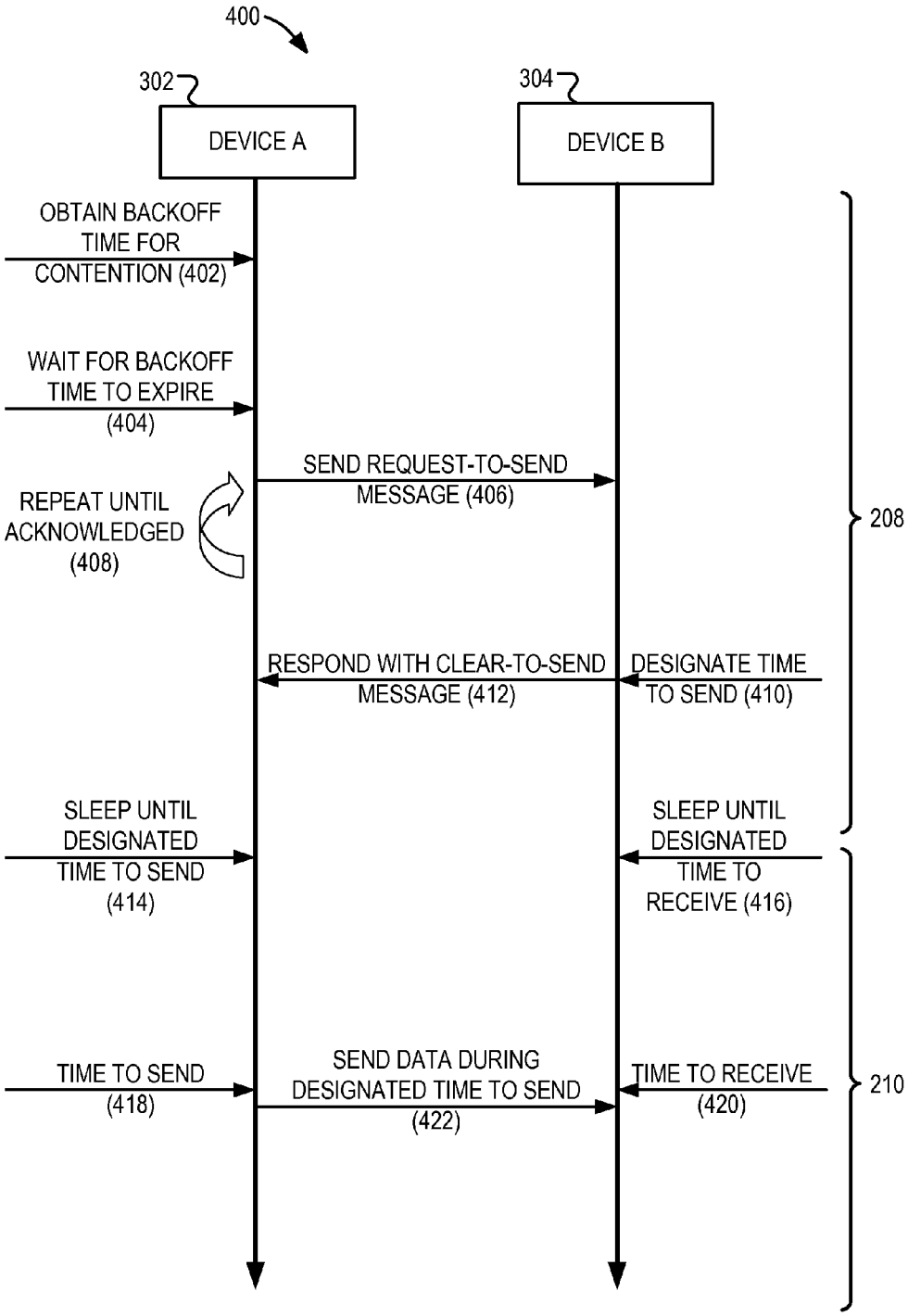
400
302
DEVICE A
304
DEVICE B
OBTAIN BACKOFF TIME FOR CONTENTION (402)
WAIT FOR BACKOFF TIME TO EXPIRE (404)
SEND REQUEST-TO-SEND MESSAGE (406)
REPEAT UNTIL ACKNOWLEDGED (408)
RESPOND WITH CLEAR-TO-SEND MESSAGE (412)
DESIGNATE TIME TO SEND (410)
208
SLEEP UNTIL DESIGNATED TIME TO SEND (414)
SLEEP UNTIL DESIGNATED TIME TO RECEIVE (416)
TIME TO SEND (418)
SEND DATA DURING DESIGNATED TIME TO SEND (422)
TIME TO RECEIVE (420)
210

FIG. 4

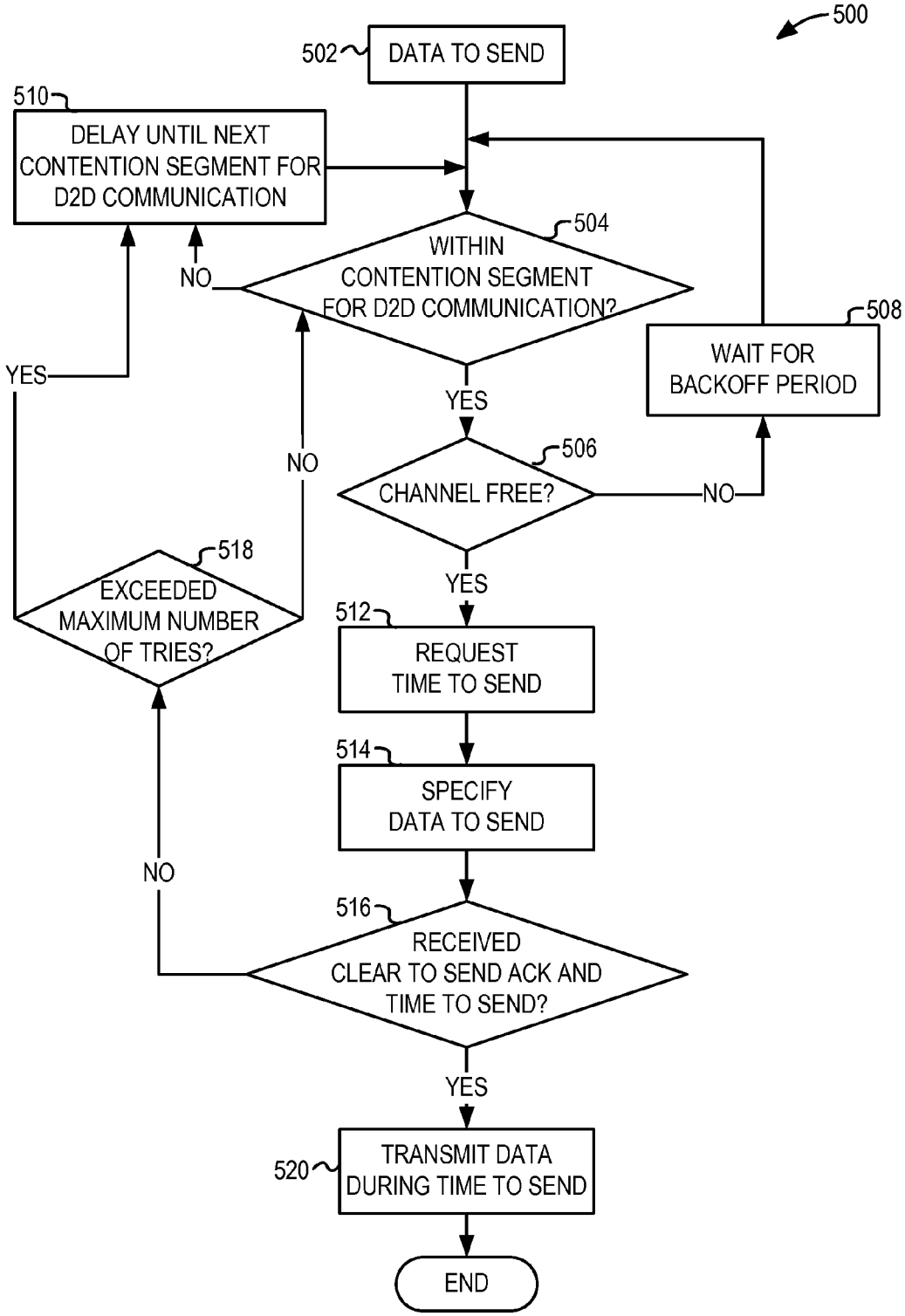
500
502
DATA TO SEND
510
DELAY UNTIL NEXT CONTENTION SEGMENT FOR D2D COMMUNICATION
504
WITHIN CONTENTION SEGMENT FOR D2D COMMUNICATION?
NO
YES
508
WAIT FOR BACKOFF PERIOD
506
CHANNEL FREE?
NO
YES
NO
518
EXCEEDED MAXIMUM NUMBER OF TRIES?
YES
512
REQUEST TIME TO SEND
514
SPECIFY DATA TO SEND
NO
516
RECEIVED CLEAR TO SEND ACK AND TIME TO SEND?
YES
520
TRANSMIT DATA DURING TIME TO SEND
END

FIG. 5

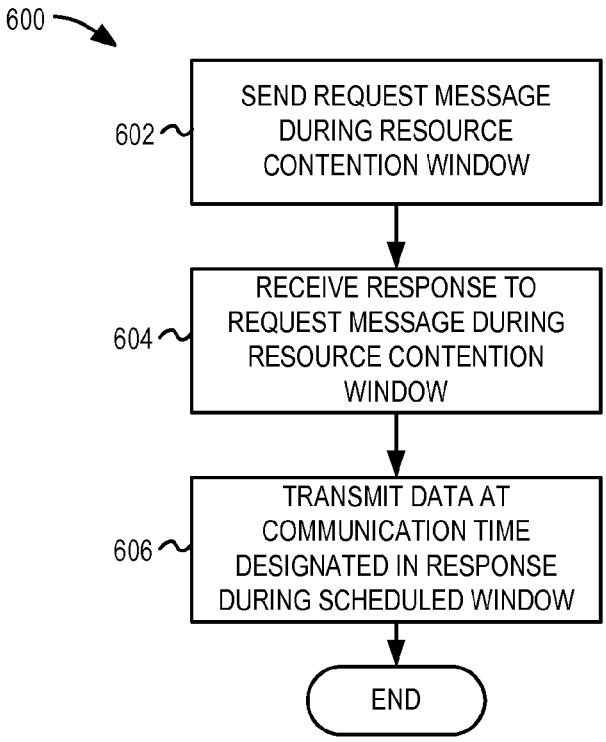
600
602
SEND REQUEST MESSAGE DURING RESOURCE CONTENTION WINDOW
604
RECEIVE RESPONSE TO REQUEST MESSAGE DURING RESOURCE CONTENTION WINDOW
606
TRANSMIT DATA AT COMMUNICATION TIME DESIGNATED IN RESPONSE DURING SCHEDULED WINDOW
END

FIG. 6A

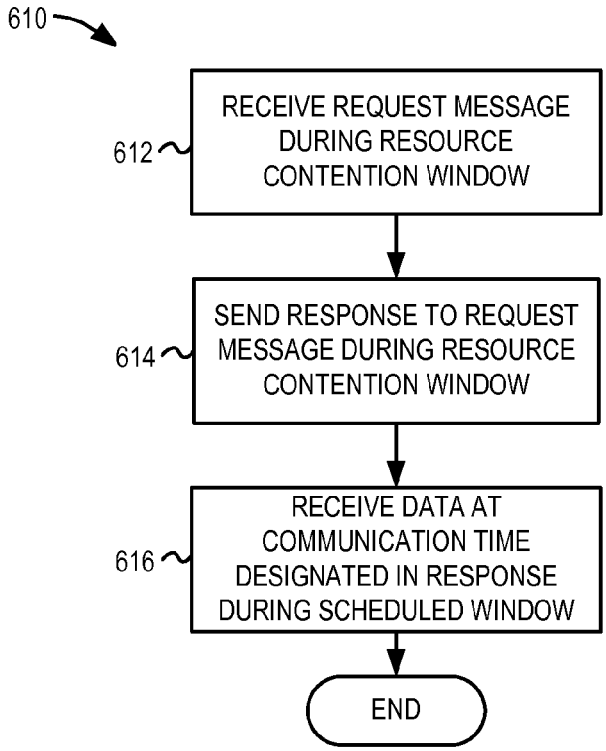
610
612
RECEIVE REQUEST MESSAGE DURING RESOURCE CONTENTION WINDOW
614
SEND RESPONSE TO REQUEST MESSAGE DURING RESOURCE CONTENTION WINDOW
616
RECEIVE DATA AT COMMUNICATION TIME DESIGNATED IN RESPONSE DURING SCHEDULED WINDOW
END

FIG. 6B

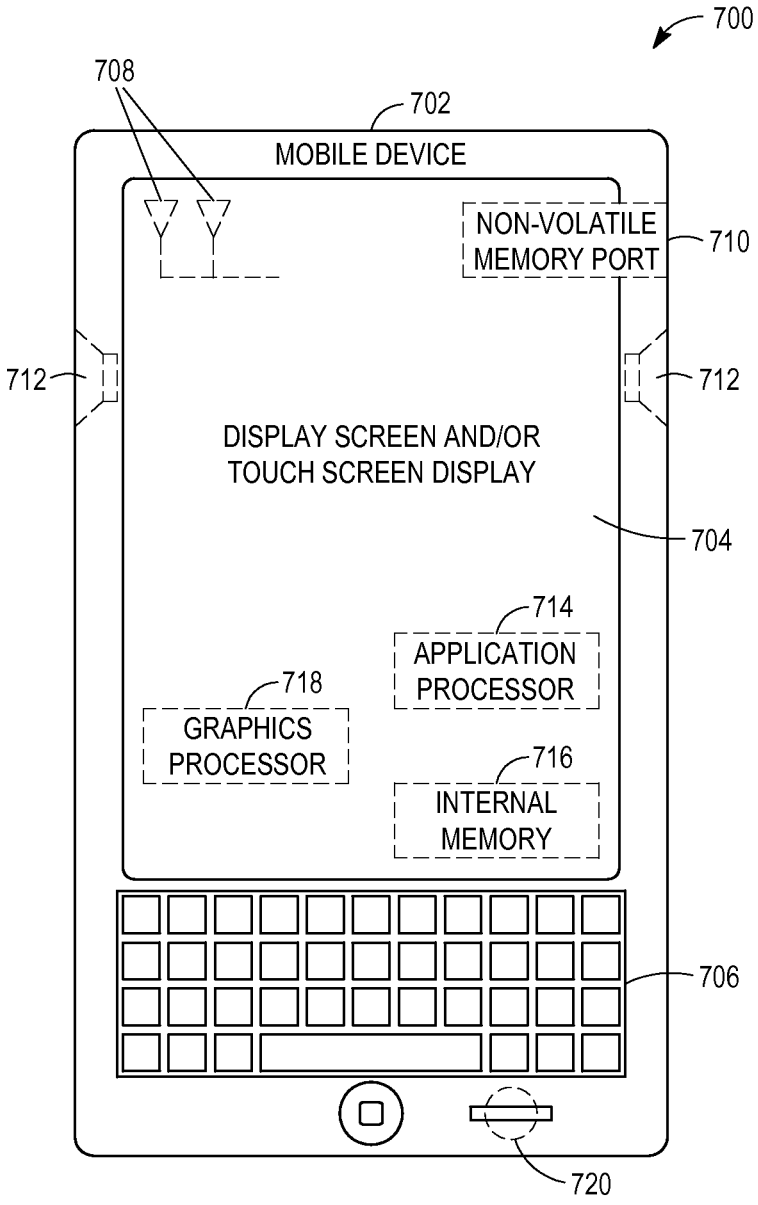
700
708
702
MOBILE DEVICE
NON-VOLATILE MEMORY PORT
710
712
712
DISPLAY SCREEN AND/OR TOUCH SCREEN DISPLAY
704
714
APPLICATION PROCESSOR
718
GRAPHICS PROCESSOR
716
INTERNAL MEMORY
706
720

FIG. 7

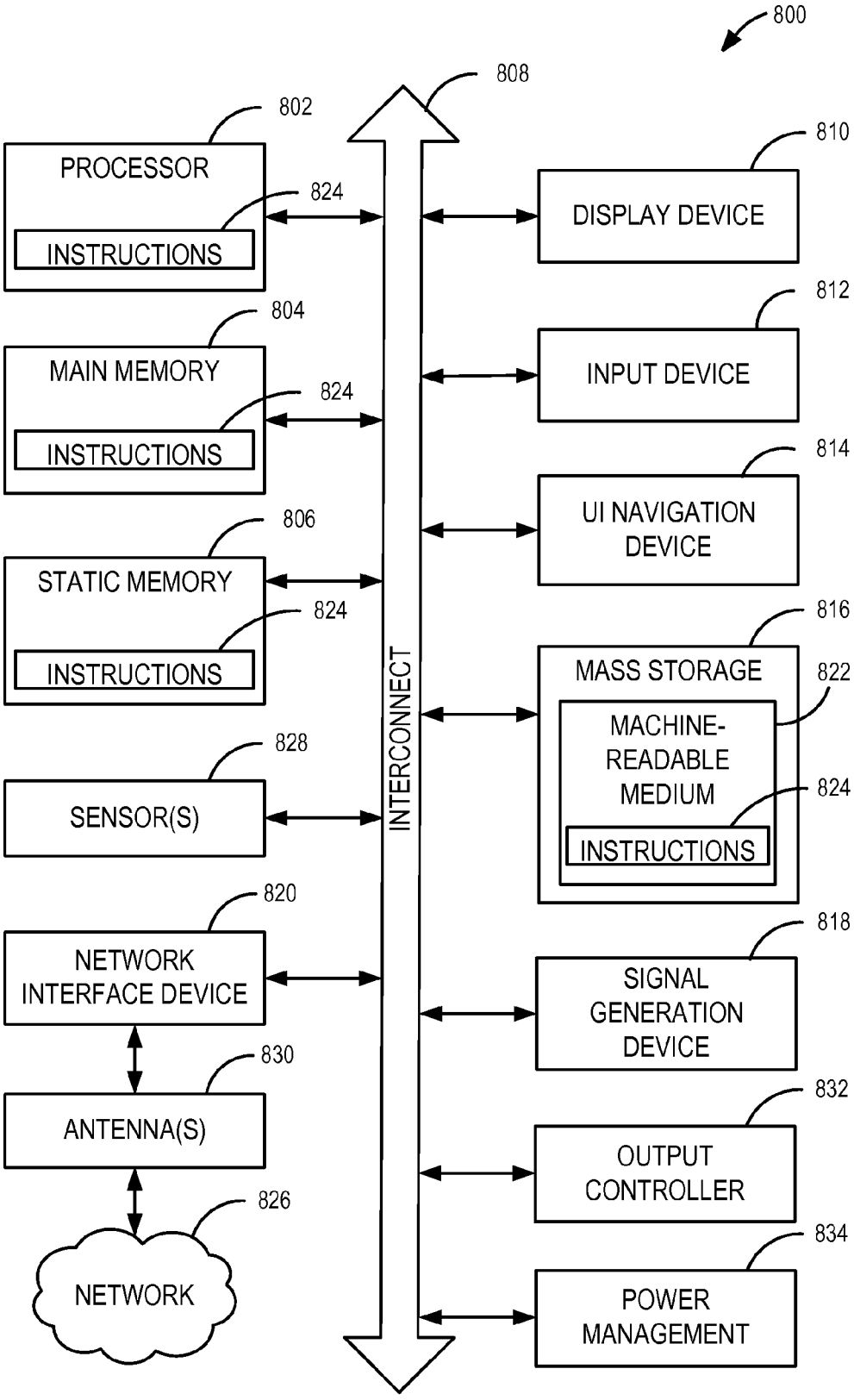
800
808
802
PROCESSOR
824
INSTRUCTIONS
804
MAIN MEMORY
824
INSTRUCTIONS
806
STATIC MEMORY
824
INSTRUCTIONS
828
SENSOR(S)
820
NETWORK INTERFACE DEVICE
830
ANTENNA(S)
826
NETWORK
INTERCONNECT
810
DISPLAY DEVICE
812
INPUT DEVICE
814
UI NAVIGATION DEVICE
816
MASS STORAGE
822
MACHINE-READABLE MEDIUM
824
INSTRUCTIONS
818
SIGNAL GENERATION DEVICE
832
OUTPUT CONTROLLER
834
POWER MANAGEMENT

FIG. 8

HIGH EFFICIENCY DISTRIBUTED DEVICE-TO-DEVICE (D2D) CHANNEL ACCESS

PRIORITY APPLICATION

This application claims priority to U.S. Provisional Patent Application Ser. No. 61/679,627, filed on Aug. 3, 2012, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

Embodiments pertain to operations and communications performed by communicating devices in wireless networks. Some embodiments relate to device-to-device (D2D) communications between devices facilitated by a wireless network.

BACKGROUND

D2D wireless communication techniques may be used to offload data communications and perform peer-to-peer communications among mobile devices and networks. D2D communications between mobile devices (e.g., user equipment (UEs)) are generally designed to complement the use of centralized communications from a wireless base station (e.g., centralized station-to-mobile communications from an evolved NodeB (eNodeB) in a 3GPP Long Term Evolution/Long Term Evolution-Advanced (LTE/LTE-A) network). D2D communications can reuse spectrum in licensed communication bands and channels used by a centralized network. Complexity exists, however, when scheduling and coordinating the D2D communications with the centralized network and independently operating devices.

For example, with certain 3GPP LTE/LTE-A standards, a time-frequency zone ("D2D zone") may be allocated by the eNodeB for D2D communications. Within the D2D zone, contention-based channel access techniques may be used to manage distributed device access to D2D communication resources. Contention-based channel access helps to minimize the scheduling and control overhead on the common interface used by the eNodeB and multiple D2D UEs. Some contention-based methods, such as Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), are not efficient, however in terms of the contention overhead and power consumption due to packet collisions and channel monitoring.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** includes a diagram of a D2D configuration for wireless communications among carrier network-connected devices according to a further described example.

FIG. **2**A illustrates a block diagram of a D2D communication space ("D2D Zone") allocated in a wireless communication frame according to a further described example.

FIG. **2**B illustrates a block diagram of a D2D communication space ("D2D Zone") having random access contention and scheduled communication divisions according to a further described example.

FIG. **3** illustrates a time-based diagram of D2D communications including random access contention and scheduled communications for multiple devices according to a further described example.

FIG. **4** illustrates an operation flow for D2D communications including random access contention and scheduled communications between two devices according to a further described example.

FIG. **5** illustrates a flowchart for a wireless communication device to perform a D2D communication using a contention and scheduled communication procedure according to a further described example.

FIG. **6**A illustrates an example method for facilitating D2D channel access for a D2D data transmission according to a further described example.

FIG. **6**B illustrates an example method for facilitating D2D channel access for a D2D data reception according to a further described example.

FIG. **7** illustrates an example mobile device on which the configurations and techniques described herein may be deployed.

FIG. **8** illustrates an example computer system that may be used as a computing platform for the computing devices described herein.

DETAILED DESCRIPTION

The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

Various techniques and configurations described herein provide for an efficient contention-based channel access scheme for D2D wireless communications. This contention-based channel access scheme may be deployed in assigned or allocated D2D communication zones or segments, such as in a D2D communication zone allocated in a carrier-based wireless communication network. The contention-based channel access scheme described herein for the D2D communications also incorporates use of scheduling techniques to coordinate the performance of the data transferred requested by the contention procedure.

In one example, the D2D communication zone is allocated into a resource allocation segment (e.g., a Random Access Channel (RACH) time period) and a scheduled communication segment (e.g., a Scheduled (SCH) time period). During the resource allocation segment, a series of request and acknowledgment messages such as a request-to-send (RTS) message and clear-to-send (CTS) message may be exchanged between devices. The RTS message may be sent by a transmitting device in the resource allocation segment to request resources in the D2D zone to perform a wireless transmission. The CTS message may be sent in response to the RTS message, to indicate a scheduled time (in the scheduled communication segment) when a receiving device will monitor the resource to receive the wireless transmission. At the scheduled time during the scheduled communication segment, the transmitting device and the receiving device can perform the D2D wireless communication.

The D2D communication techniques described herein provide a joint contention and scheduling mechanism that addresses deficiencies of exclusive contention or scheduling techniques. One commonly used contention technique, CSMA/CA, is deployed in communications for wireless networks such as IEEE 802.11 standard-compliant implementations. CSMA/CA implementations typically use a backoff counter to wait a random number of slots to help find an opportunity to send the data packet. If the channel is idle, then a packet is sent.

The D2D communication technique described herein enables the actual data transmission to be scheduled and

reserved. This ensures that a particular data packet can be transmitted without interference, while using contention-based techniques to request the scheduling. This enables a method which can transform the original contention mechanism into a distributed scheduling mechanism, to cause less contention and network pollution. Further, use of the distributed scheduling mechanism enables multiple pairs of devices to exchange data in a scheduled window. Information from the scheduling window can be used to further coordinate power usage, communications, and other aspects of the D2D wireless network.

FIG. **1** illustrates a D2D networking configuration **100** for wireless communications among carrier network-connected devices **104**A, **104**B, **104**C according to a further described example. As illustrated, a carrier-based network (e.g., a LTE/LTE-A cell network operating according to a standard from a 3GPP standards family) is established by a carrier network system **102** (e.g., an eNodeB) with mobile devices **104**A, **104**B, **104**C (e.g., user equipment (UE)). The carrier-based network includes network connections **106**A, **106**B, **106**C to the mobile devices **104**A, **104**B, **104**C, respectively. The mobile devices **104**A, **104**B, **104**C are illustrated as conforming to a variety of form factors, including a smartphone **104**A, a mobile phone handset **104**B, and a personal computer (PC) **104**C having an integrated or external wireless network communication device.

The D2D communications may be performed among the various mobile devices **104**A, **104**B, **104**C using the contention and scheduling techniques for D2D connections described herein. Pairs of D2D-capable communication devices can talk to each other, and may be co-located in a same area. Specifically, a D2D connection **108** may be established between smartphone **104**A and mobile phone **104**B; a D2D connection **110** may be established between mobile phone **104**B and personal computer **104**C; and a D2D connection **112** may be established between smartphone **104**A and personal computer **104**C.

The carrier-based network controlled by the carrier network system **102** may be used to facilitate operations of the D2D connections **108**, **110**, **112**. The carrier-based network (and various devices, subsystems, and components within the carrier-based network, such as an eNodeB) may schedule or coordinate a communication window and timing for allowed D2D capabilities. The carrier network system **102** may also communicate availability and connection details among the various mobile devices **104**A, **104**B, **104**C, and indicate the type of data to be communicated using the D2D connections, or when usage of the D2D connections is required or encouraged. The D2D connections **108**, **110**, **112** may be conducted among the receiving devices **104**A, **104**B, **104**C using the same or different communication frequencies and spectrum as that of the carrier-based network. This may include licensed or unlicensed spectrum using the same network protocol (e.g., a network protocol operating according to a LTE, LTE-A, or other 3GPP standard) or other network protocols (e.g., a network protocol operating according to a standard from an IEEE 802.11 or 802.16 standards family, or a Bluetooth standard promulgated from the Bluetooth Special Interest Group).

FIG. **2**A illustrates a block diagram of a D2D communication space allocated in a wireless communication frame **200** according to a further described example. As depicted, the wireless communication frame **200** may include a downlink segment **202**, including a set of downlink subframes, and an uplink segment **204**, including a series of uplink subframes. The uplink segment **204** may be further segmented to include resources allocated for D2D communications. As illustrated, this segment allocated for D2D communications is referred to herein as the "D2D Zone" **206**. Any D2D wireless transmissions among the various mobile devices **104**A, **104**B, **104**C may be configured to start and end within the D2D Zone **206**.

FIG. **2**B illustrates a block diagram of an example D2D communication space (the D2D Zone **206**) having random access contention and scheduled communication divisions according to a further described example. In a frame-based time-frequency area, the D2D Zone **206** may be defined and partitioned in a time domain as shown in FIG. **2**B. The random access contention segment of the D2D Zone **206** is referred to herein as the D2D random access channel "D2D RACH" segment **208**. The scheduled communication segment of the D2D Zone **206** is referred to herein as the D2D shared channel "D2D SCH" segment **210**. Although not illustrated, the D2D Zone **206** also may be further segmented or partitioned for other purposes.

In one example implementation, all contentions for D2D communication resource occur only in the D2D RACH segment **208**. This results in only a small number of possible D2D devices (the winners of the contention) actively communicating in the D2D SCH segment **210**. Use of a contention resource in the D2D RACH segment **208** followed by scheduling in the D2D SCH segment **210** enables devices to effectively coordinate operations, particularly where a large number of potential devices may be communicating.

Limiting contention to the D2D RACH segment **208** and actual data transmissions to the D2D SCH segment **210** may be used to retain the flexibility of contention-based D2D communication, while enabling the reduction of power consumption for many devices. For example, D2D devices not involved with a scheduled communication may choose to enter a power-saving or reduced communication mode during the duration of the D2D SCH segment **210**. Likewise, D2D devices which are involved with a scheduled communication during only a portion of the D2D SCH segment **210** may choose to wake from a low power state on an as-needed basis (and re-enter the low power state) according to the schedule.

In contrast, the power consumption of devices implementing various contention techniques such as CSMA/CA may be much higher than with the presently described technique. This is because with the use of CSMA/CA, each active device is generally required to be active at all times, to detect the received packets over the wireless channel (and prevent the device from missing a packet addressed to it). Scheduling multiple D2D transmissions, one at a time within a scheduling window, enables many D2D devices to reduce power and channel monitoring requirements.

FIG. **3** illustrates a time-based diagram **300** of D2D communications including random access contention and scheduled communications for multiple devices **302**, **304**, **306**, **308** (in the D2D Zone **206** or other designated D2D communication time) according to a further described example. As depicted, Device A **302** and Device C **306** each are intended to schedule transmissions (**318**, **320**) to Device B **304** and Device D **308** respectively.

During the D2D RACH segment **208**, all active D2D devices **302**, **304**, **306**, **308** monitor the channel for potential transmission or reception. In the example of FIG. **3**, there is a request-to-send message **310** transmitted by Device A **302** to indicate a request to perform a data transmission to Device B **304**, and a request-to-send message **314** transmitted by Device C **306** to indicate a request to perform a data transmission to Device D **308**. These request-to-send messages **310**, **314** used to invoke responses in the form of a clear-to-send message **312** from Device B **304**, and a clear-to-send message **316** from Device D **308**.

During the D2D RACH Segment **208**, the device implements a contention-based technique to manage channel access for multiple transmissions over the wireless communication medium. This may be performed through the use of a collision avoidance technique with the generation of a backoff time for a busy channel, similar to use of a CSMA/CA technique. When the backoff time expires, and time remains within the D2D RACH segment **208**, a transmitting device may send a request-to-send message to a receiving device. If a receiving device receives the request-to-send message successfully, the receiving device may respond by a clear-to-send message.

The clear-to-send response message is distinguishable from existing CSMA/CA mechanisms used in IEEE 802.11 or other wireless network standards, due to the inclusion of an explicit transmission or scheduling time in the response message. The transmission time, denoted as time-to-send, may be specified in a clear-to-send message such that a transmitting device knows when to turn on its transmitter to send the packet (e.g., with Device A's data transmission **318** during D2D SCH segment **210**). Further, the clear-to-send message may be used to inform other listening/receiving devices in the network whether the scheduled channel will be in use by the communicating devices.

When a contention mechanism indicates that previous use of the contention channel is now concluded (such as a backoff time expires for Device C **306** in the D2D RACH channel **208**, and the channel is detected as being available), Device C **306** may send a request-to-send message **314** to Device D **316**. A time-to-send indication is specified in this message. If Device D **308** receives the request-to-send message successfully, Device D **308** will respond by a clear-to-send message **316** with a time-to-send indication to inform both Device C **306** and other listening devices (e.g., Device A **302**, Device B **304**) of the transmission time for Device C's data transmission **320**.

The size of the request-to-send/clear-to-send message packet may be configured to be small to conserve bandwidth and resources. The request-to-send/clear-to-send message may be configured to only provide a simple indication of how much time to reserve (in the request-to-send packet) and what time is reserved (in the clear-to-send response packet). Device neighbors of the transmitting and receiving devices can also observe the request-to-send/clear-to-send packets to learn about the scheduling and specific time reservation. In contrast, with use of request-to-send/clear-to-send packets in IEEE 802.11 standard networks, there is no such information on scheduling or timing within the clear-to-send message packet. Rather, the clear-to-send message in IEEE 802.11 standard networks is used to invoke immediate transmission of data and not a scheduled transmission of data in a separate time window.

Thus, request-to-send/clear-to-send packets are exchanged in the D2D RACH segment **208**, and scheduling is established for the actual data transmission(s) over the wireless channel in the D2D SCH segment **210**. This enables active and observing devices to know exact transmission times and keep track of channel usage. During the duration of the D2D SCH segment **210**, only successfully scheduled devices involved in transmission and receipt in the D2D RACH segment **208** need to be powered and active at the scheduled time. For example, when it is the time for Devices A and B **302**, **304** to transmit and receive with data communication **318**, Devices C and D **306**, **308** can enter or maintain a sleep/power-saving mode to minimize power consumption. Likewise, Devices A and B **302**, **304** can enter or maintain a sleep/power-saving mode during the time that devices C and D **306**, **308** communicate with data transmission **320**.

FIG. **4** illustrates an operation flow **400** for D2D communications including random access contention and scheduled communications between two devices (Device A **302** and Device B **304**) according to a further described example. During the D2D RACH segment **208**, both Device A **302** and Device B **304** are configured to listen to the wireless communication medium for any signaling.

Device A **302** obtains access to the D2D RACH segment **208** using a contention access technique. As illustrated, this may include a CSMA/CA-type of backoff technique, including obtaining a backoff time (operation **402**) and waiting for the backoff time to expire (operation **404**). Device A **302** sends the request-to-send (RTS) message (operation **406**) to Device B **304**, repeating the RTS message until acknowledged (operation **408**) or until a specified number of tries is exceeded (unless the D2D RACH segment **208** has concluded).

Device B **304** responds by sending a clear-to-send message (operation **412**), indicating a designated time-to-send (operation **410**) of when Device A **302** can start to send data packets of the data transmission. Upon the conclusion of the D2D RACH segment **208** and the start of the D2D SCH segment **210**, Device A **302** and Device B **304** may enter sleep modes until the designated time to send (operation **414**) and time to receive (operation **416**) respectively. At the time to send (operation **418**) and the time to receive (operation **420**), the data can be transmitted over the wireless medium from Device A **302** to Device B **304**.

The time to send (designated in operation **410**) may be indicated by an offset time t**1** from the start of the D2D SCH segment **210**. The offset time t**1** can be defined in some resolved time unit of the carrier network, e.g. a number of time slots. (Likewise, when another device, such as Device D **308** of FIG. **3**, sends a clear-to-send response, the clear-to-send response message may indicate when Device C **306** of FIG. **3** can start to send data packets, at an offset time t**2** from the start of the D2D SCH Segment **210**).

The boundary between the D2D RACH segment **208** and the D2D SCH segment **210** can be set explicitly or implicitly. Restated, the amount of time for actual scheduled transmissions, versus contention for the scheduled transmission, can be fixed or adjusted. For explicit definition, this boundary can be defined by the eNodeB, another other network entity, or set according to pre-defined rules for D2D communications.

For implicit definition, the boundary can be adjusted by D2D devices in each frame (e.g., during each D2D RACH segment **208**, or for multiple frames using one scheduling effective for N number of frames). The boundary may be adjusted based upon the successful channel reservations that are known to all devices. The last device that sends a request-to-send message can calculate if the duration of the D2D RACH segment **208** plus the duration of the D2D SCH segment **210**, including the outstanding request, might exceed the D2D Zone **206**. If the answer is no (which means there is enough time remaining in the D2D Zone **206** to conduct the request and the data transmission), the transmitting device can send a request-to-send message. Thus, the boundary of the D2D RACH segment **208** and the D2D SCH segment **210** can be set automatically after the reception of a clear-to-send message sent from the last device in the D2D RACH segment **208**.

Before providing a request-to-send message or a response to the request-to-send (a clear-to-send message), the devices may perform a calculation to ensure that the duration of all

scheduled data transmissions will not exceed the D2D zone boundary. If the total transmission will exceed the D2D zone boundary, the transmission(s) may be split up, or the transmission(s) may be rescheduled to another D2D zone. D2D devices may know or may be informed of the size (duration) of available D2D zone resources (e.g., how many time slots exist for usage with the D2D communications). Thus, D2D devices or UEs can decide scheduling of a shared channel by themselves using distributive techniques.

FIG. **5** illustrates a flowchart **500** for a device to schedule a D2D communication using a contention procedure according to some embodiments. As shown in operation **502**, a transmitting wireless communication device has data to send via a D2D communication. In decision **504**, a determination is made whether the contention segment (e.g., window) for the D2D communication is ongoing. If not, the data transmission may be delayed until the next contention segment for D2D communications (operation **510**).

If as a result (of decision **504**) the contention segment for the D2D communication is ongoing, a determination is made whether the wireless channel is free (decision **506**). If the channel is not free, the data transmission is delayed for at least a backoff period (operation **508**). If the channel is free, the device may proceed with transmitting a request for scheduled data resources (operation **512**), and a specification of the size or other attributes of the data to send (operation **514**). A determination is then made whether the transmitting wireless communication device receives a clear-to-send acknowledgement and a time to send within a period of time (decision **516**). If no clear-to-send acknowledgment has been received within a period of time, then a determination is made whether the number of times that the request was transmitted exceeds a maximum number of attempts (decision **518**). If the maximum number of attempts is not exceeded, then the contention process is repeated (decision **504**); if the maximum number of attempts is exceeded, then the D2D communication is delayed until a next contention segment (operation **510**). If, however, the clear-to-send acknowledgment and the time to send are successfully received, then the data transmission may occur during the designated time to send (operation **520**).

FIG. **6**A illustrates a flowchart **600** of an example method for controlling D2D channel access of a D2D data transmission, from a transmitting device with a series of time windows, according to a further described example. As depicted, in operation **602**, a transmitting device sends a request message during a resource contention window of the D2D time-frequency zone. The transmission of the request message may be delayed based on a backoff counter, detection of use of the contention channel, randomized access times, waiting periods, or other collision avoidance mechanisms.

In operation **604**, still during the resource contention window, the transmitting device receives a response to the request message originating from the receiving device. The response includes a designated communication time for use during a scheduled window of the D2D time-frequency zone.

In operation **606**, during the scheduled window of the D2D time-frequency zone, the data will be transmitted at the designated communication time. Various scheduling and re-scheduling mechanisms may be employed within the D2D time-frequency zone (or in another D2D time-frequency zone) to re-transmit the data upon failure or interruption of the data transmission, or lack of acknowledgment. The data transmission is then processed by the receiving device upon the successful receipt.

FIG. **6**B illustrates a flowchart **610** of an example method for controlling D2D channel access of a D2D data reception at a receiving device according to a further described example. As depicted, in operation **612**, a receiving device receives a request message during a resource condition window of the D2D time-frequency zone. The receipt of the request message may indicate the size of requested data transmission and other communication parameters as necessary to arrange scheduling.

In operation **614**, still during the resource contention window, the receiving device transmits a response to the request message for receipt by the transmitting device. The response includes a designated communication time for use during a scheduled window of the D2D time-frequency zone.

In operation **616**, during the scheduled window of the D2D time-frequency zone, the data will be received from the transmitting device starting at the designated communication time. The data transmission may be further processed by the receiving device upon the successful receipt, and an acknowledgment may be sent in response to receipt of the data.

The techniques and configurations described herein may be extended to operate in other configurations. For example, the techniques may be used in connection with a peer-to-peer or point-to-point network which involves connections over a plurality of devices (e.g., connections involving multiple hops). The techniques may also be used in connection with a standardized protocol defining response messages formats, timing, and conditions. Thus, implementations of the presently described contention and scheduling techniques are not limited to implementations with a 3GPP standard, but may also extend to device-to-device, peer-to-peer, point-to-point, machine-to-machine, and distributed networks in accordance with IEEE 802.11 standards, IEEE 802.16 standards, and the like.

Functionality for the present technique may be incorporated in components or modules in a computing system (including a mobile device), a wireless network adapter, a wireless transceiver control, circuitry for such systems and devices, and in hardware and software implementations. Further, various methods or techniques, or certain aspects or portions of the functionality described herein, may take the form of program code (i.e., instructions) embodied in tangible media, such as flash memory, CD/DVD-ROMs, hard drives, portable storage devices, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the various techniques. In the case of program code execution on programmable computers, the computing device may include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. One or more programs that may implement or utilize the various techniques described herein may use an application programming interface (API), reusable controls, and the like. Such programs may be implemented in a high level procedural or object oriented programming language to communicate with a computer system. However, the program(s) may be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or interpreted language, and combined with hardware implementations.

FIG. **7** provides an example illustration of a mobile device **700**, such as a UE, a mobile station (MS), a mobile wireless device, a mobile communication device, a tablet, a handset, or other type of mobile wireless device. The mobile device **700** may include one or more antennas **708** within housing **702** that are configured to communicate with a base station (BS), an eNodeB, or other type of wireless wide area network (WWAN) access point. The mobile device **700** may be configured to communicate using at least one wireless commu-

nication standard including 3GPP LTE, WiMAX, High Speed Packet Access (HSPA), Bluetooth (the term "Bluetooth" as used herein referring to a short-range digital communication protocol including a short-haul wireless protocol frequency-hopping spread-spectrum (FHSS) communication technique operating in the 2.4 GHz spectrum), and Wi-Fi. The mobile device **700** may communicate using separate antennas for each wireless communication standard or shared antennas for multiple wireless communication standards. The mobile device **700** may communicate in a wireless local area network (WLAN), a wireless personal area network (WPAN), and/or a WWAN.

FIG. **7** also provides an illustration of a microphone **720** and one or more speakers **712** that may be used for audio input and output from the mobile device **700**. The display screen **704** may be a liquid crystal display (LCD) screen, or other type of display screen such as an organic light emitting diode (OLED) display. The display screen **704** may be configured as a touch screen. The touch screen may use capacitive, resistive, or another type of touch screen technology. An application processor **714** and a graphics processor **718** may be coupled to internal memory **716** to provide processing and display capabilities. A non-volatile memory port **710** may also be used to provide data input/output options to a user. The non-volatile memory port **710** may also be used to expand the memory capabilities of the mobile device **700**. A keyboard **706** may be integrated with the mobile device **700** or wirelessly connected to the mobile device **700** to provide additional user input. A virtual keyboard may also be provided using the touch screen.

FIG. **8** is a block diagram illustrating an example computer system machine upon which any one or more of the methodologies herein discussed may be run. Computer system **800** may be embodied as the computing device **104**, mobile device **106**, mobile device **700** (from FIGS. **1** and **7**), or any other computing platform described or referred to herein. In alternative embodiments, the machine operates as a standalone device or may be connected (e.g., networked) to other machines. In a networked deployment, the machine may operate in the capacity of either a server or a client machine in server-client network environments, or it may act as a peer machine in peer-to-peer (or distributed) network environments. The machine may be a personal computer (PC) that may or may not be portable (e.g., a notebook or a netbook), a tablet, a set-top box (STB), a gaming console, a Personal Digital Assistant (PDA), a mobile telephone or smartphone, a web appliance, a network router, switch or bridge, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein.

Example computer system **800** includes a processor **802** (e.g., a central processing unit (CPU), a graphics processing unit (GPU) or both), a main memory **804** and a static memory **806**, which communicate with each other via an interconnect **808** (e.g., a link, a bus, etc.). The computer system **800** may further include a video display unit **810**, an alphanumeric input device **812** (e.g., a keyboard), and a user interface (UI) navigation device **814** (e.g., a mouse). In one embodiment, the video display unit **810**, input device **812** and UI navigation device **814** are a touch screen display. The computer system **800** may additionally include a storage device **816** (e.g., a drive unit), a signal generation device **818** (e.g., a speaker), an output controller **832**, a power management controller **834**, and a network interface device **820** (which may include or operably communicate with one or more antennas **830**, transceivers, or other wireless communications hardware), and one or more sensors **828**, such as a Global Positioning System (GPS) sensor, compass, location sensor, accelerometer, or other sensor.

The storage device **816** includes a machine-readable medium **822** on which is stored one or more sets of data structures and instructions **824** (e.g., software) embodying or utilized by any one or more of the methodologies or functions described herein. The instructions **824** may also reside, completely or at least partially, within the main memory **804**, static memory **806**, and/or within the processor **802** during execution thereof by the computer system **800**, with the main memory **804**, static memory **806**, and the processor **802** also constituting machine-readable media.

While the machine-readable medium **822** is illustrated in an example embodiment to be a single medium, the term "machine-readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more instructions **824**. The term "machine-readable medium" shall also be taken to include any tangible medium that is capable of storing, encoding, or carrying instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the present disclosure or that is capable of storing, encoding or carrying data structures utilized by or associated with such instructions. The term "machine-readable medium" shall accordingly be taken to include, but not be limited to, solid-state memories, and optical and magnetic media. Specific examples of machine-readable media include non-volatile memory, including, by way of example, semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks such as internal hard disks and removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks.

The instructions **824** may further be transmitted or received over a communications network **826** using a transmission medium via the network interface device **820** utilizing any one of a number of well-known transfer protocols (e.g., HTTP). Examples of communication networks include a LAN, WAN, the Internet, mobile telephone networks, Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Wi-Fi, 3G, and 4G LTE/LTE-A or WiMAX networks). The term "transmission medium" shall be taken to include any intangible medium that is capable of storing, encoding, or carrying instructions for execution by the machine, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software.

Other applicable network configurations may be included within the scope of the presently described communication networks. Although examples were provided with reference to a local area wireless network configuration and a wide area Internet network connection, it will be understood that communications may also be facilitated using any number of PANs, LANs, and WANs, using any combination of wired or wireless transmission mediums.

The embodiments described above may be implemented in one or a combination of hardware, firmware, and software. Embodiments may also be implemented as instructions stored on a computer-readable storage device, which may be read and executed by at least one processor to perform the operations described herein. A computer-readable storage

device may include any non-transitory mechanism for storing information in a form readable by a machine (e.g., a computer). For example, a computer-readable storage device may include read-only memory (ROM), random-access memory (RAM), magnetic disk storage media, optical storage media, flash-memory devices, and other storage devices and media.

It should be understood that the functional units or capabilities described in this specification may have been referred to or labeled as components or modules, in order to more particularly emphasize their implementation independence. For example, a component or module may be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A component or module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like. Components or modules may also be implemented in software for execution by various types of processors. An identified component or module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified component or module need not be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the component or module and achieve the stated purpose for the component or module.

Indeed, a component or module of executable code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within components or modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network. The components or modules may be passive or active, including agents operable to perform desired functions.

Additional examples of the presently described method, system, and device embodiments include the following, non-limiting configurations. Each of the following non-limiting examples may stand on its own, or may be combined in any permutation or combination with any one or more of the other examples provided below or throughout the present disclosure.

Example 1 includes the subject matter embodied by a wireless communication device (e.g., a UE), comprising processing circuitry arranged to communicate with an evolved Node B (eNodeB) using a 3GPP Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) network connection and to facilitate device-to-device communications with a receiving UE using a direct network connection, by performing operations to: send a request message to a receiving UE, during a resource contention window, the resource contention window allocated for scheduling device-to-device communications in a wireless channel using a contention channel access technique, the request message indicating a size for a data transmission; receive a response to the request message, from the receiving UE, the response confirming the request message and designating a transmission time for the data transmission, and the designated transmission time occurring within a scheduled transmission window allocated for conducting the device-to-device communications; and perform the data transmission with the receiving UE, during the scheduled transmission window allocated for conducting the device-to-device communications, on the wireless channel at the designated transmission time.

In Example 2, the subject matter of Example 1 can optionally include the processing circuitry being further arranged to perform operations to: maintain a low-power mode at the wireless communication device, beginning at a start of the scheduled transmission window until the designated transmission time.

In Example 3, the subject matter of one or any combination of Examples 1-2 can optionally include the processing circuitry being further arranged to perform operations to: perform a contention channel access technique to obtain access to the wireless channel during the resource contention window, the contention channel access technique including obtaining a backoff time for contention during the resource contention window, and waiting for the backoff time to expire, prior to sending the request message during the resource contention window.

In Example 4, the subject matter of one or any combination of Examples 1-3 can optionally include the processing circuitry being further arranged to perform operations to: resend the request message during the resource contention window in response to the request message not being acknowledged by the receiving device within a period of time.

In Example 5, the subject matter of one or any combination of Examples 1-4 can optionally include the resource contention window and the scheduled transmission window being allocated in subframes for an uplink period defined in a carrier network.

In Example 6, the subject matter of one or any combination of Examples 1-5 can optionally include the uplink period being defined in the carrier network according to a standard provided from a 3GPP Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) standards family.

In Example 7, the subject matter of one or any combination of Examples 1-6 can optionally include the resource contention window and the scheduled transmission window being allocated for peer-to-peer communications among devices according to a standard from an IEEE 802.11 standards family, or for machine-to-machine communications among devices according to a standard from an IEEE 802.16 standards family.

In Example 8, the subject matter of one or any combination of Examples 1-7 can optionally include the resource contention window and the scheduled transmission window occurring in a zone allocated for the device-to-device communications in a wireless channel, wherein a size of the resource contention window relative to the scheduled transmission window is configured to change based on characteristics of one or more data transmissions requested during the resource contention window.

Example 9 can include, or can optionally be combined with all or portions of the subject matter of one or any combination of Examples 1-8 to include a method performed by a dual-mode user equipment (UE) for facilitating device-to-device communications with a receiving wireless communications device, the dual-mode UE configured for communications with a carrier-based network in addition to the device-to-device communications, and the method comprising: accessing a wireless channel using a contention channel access technique, within a resource contention window allocated for scheduling device-to-device communications in a wireless channel, the resource contention window occurring during a device-to-device communications period indicated by a carrier-based network; transmitting a request message to the

receiving communications device, within the resource contention window, to obtain a designated transmission time for a device-to-device data transmission; and conducting the device-to-device data transmission from the transmitting communications device to the receiving communications device at the designated transmission time, within a scheduled transmission window allocated for performing for the device-to-device communications in the wireless channel, the scheduled transmission window occurring during a device-to-device communications period indicated by the carrier-based network.

In Example 10, the subject matter of Example 9 can optionally include conducting a sleep mode within the scheduled transmission window; and interrupting the sleep mode within the scheduled transmission window to conduct the device-to-device data transmission.

In Example 11, the subject matter of one or any combination of Examples 9-10 can optionally include the contention access technique including obtaining a backoff time for contention within the resource contention window, and waiting for the backoff time to expire, prior to transmitting the request message within the resource contention window.

In Example 12, the subject matter of one or any combination of Examples 9-11 can optionally include the resource contention window and the scheduled transmission window being allocated in one or more subframes for a scheduled uplink period defined for a carrier network, and wherein the scheduled uplink period is an uplink period established by a carrier network operating according to a standard provided from a 3GPP Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) standards family.

Example 13 can include, or can optionally be combined with all or portions of the subject matter of one or any combination of Examples 1-12 to include User Equipment (UE) comprising: a transceiver comprising circuitry including physical layer circuitry and media-access control layer circuitry, the circuitry arranged to establish device to device channel access in a wireless communication medium, by performing operations to: receive a request message, from a transmitting device, to conduct a data transmission during a resource contention window, the resource contention window being allocated for wireless device-to-device communications, the request message indicating a size for a data transmission and being sent from the transmitting device on the wireless communication medium using a contention-based technique; send a response to the request message, the response confirming the request message and designating a time for the data transmission, the transmission time occurring within a scheduled transmission window allocated for the wireless device-to-device communications; and receive the data transmission from the transmitting device via the wireless communication medium at the designated time, during the scheduled transmission window allocated for the wireless device-to-device communications; wherein the resource contention window and the scheduled transmission window are allocated for the wireless device-to-device communications according to timing designated by a network controlled by an evolved Node B (eNodeB).

In Example 14, the subject matter of Example 13 can optionally include the circuitry being further arranged to perform operations to: maintain, from the transmitting device, a low-power mode beginning at a start of the scheduled transmission window until the designated time.

In Example 15, the subject matter of one or any combination of Examples 13-14 can optionally include the circuitry being further arranged to perform operations to: obtain a backoff time for contention during the resource contention window, and waiting for the backoff time to expire, prior to sending the response to the request message, wherein the response to the request message is sent during the resource contention window.

In Example 16, the subject matter of one or any combination of Examples 13-15 can optionally include the circuitry being further arranged to perform operations to: provide an acknowledgement of data received from the transmitting device in response to the data transmission.

In Example 17, the subject matter of one or any combination of Examples 13-16 can optionally include the resource contention window and the scheduled transmission window being allocated in time slots for a scheduled uplink period defined for a carrier network provided from the eNodeB.

In Example 18, the subject matter of one or any combination of Examples 13-17 can optionally include the scheduled uplink period being an uplink period defined according to a standard provided from a 3GPP Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) standards family.

Example 19 can include, or can optionally be combined with all or portions of the subject matter of one or any combination of Examples 1-18 to include a method for facilitating device to device communications with a transmitting device, comprising: processing a request message to conduct a data transmission during a resource contention window and obtain a time of transmission for the data transmission, the request message indicating a size for the data transmission and being sent from the transmitting device over a wireless medium using a contention channel access technique to access the wireless medium; transmitting a response to the request message, the response confirming the request message and designating a transmission time for the data transmission, the transmission time designated within a scheduled transmission window; and processing the data transmission from the transmitting device on the wireless channel received at a designated communication time during the scheduled transmission window; wherein the scheduled transmission window and the resource contention window are designated by an evolved Node B (eNodeB) for performance of wireless device-to-device communications on the wireless medium.

In Example 20, the subject matter of Example 19 can optionally include conducting a sleep mode during the scheduled transmission window; and interrupting the sleep mode during the scheduled transmission window to conduct the data transmission.

In Example 21, the subject matter of one or any combination of Examples 19-20 can optionally include the response to the request message being transmitted via the wireless medium in connection with the contention channel access technique, wherein the contention channel access technique includes obtaining a backoff time for contention during the resource contention window, and waiting for the backoff time to expire, prior to transmitting the response to the request message during the resource contention window.

In Example 22, the subject matter of one or any combination of Examples 19-21 can optionally include the resource contention window and the scheduled transmission window being allocated for a scheduled uplink period defined for a network operating according to a standard provided from a 3GPP Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-A) standards family.

The Abstract is provided to allow the reader to ascertain the nature and gist of the technical disclosure. It is submitted with the understanding that it will not be used to limit or interpret the scope or meaning of the claims. The following claims are

hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

What is claimed is:

1. A user equipment (UE), comprising:

physical layer circuitry arranged to communicate with an evolved Node B (eNodeB) using a 3GPP Long Term Evolution (LTE) or Long-Term Evolution-Advanced (LTE-A) network connection and to facilitate device-to-device communications with a receiving UE using a direct network connection; and

media-access control (MAC) layer circuitry arranged to:

send via physical layer (PHY) circuitry a request message to a receiving UE, during a resource contention window allocated from a device-to-device portion of an uplink segment of an LTE or LTE-A frame, the resource contention window allocated for scheduling device-to-device communications in a wireless channel using a random access contention channel access technique, the request message indicating a size for a data transmission;

receive a response to the request message via the PHY layer circuitry from the receiving UE, the response confirming the request message and designating a transmission time for the data transmission, the designated transmission time determined by the receiving UE and occurring within a first portion of a scheduled transmission window of the device-to-device portion of the uplink segment, the scheduled transmission window allocated for conducting the device-to-device communications, and wherein other devices may transmit in a second portion of the scheduled transmission window;

perform the data transmission with the receiving UE via the PHY layer circuitry, during the scheduled transmission window allocated for conducting the device-to-device communications, on the wireless channel at the designated transmission time; and

refrain from transmitting during the second portion of the scheduled transmission window.

2. The UE of claim **1**, the MAC layer circuitry further arranged to perform operations to:

maintain a low-power mode at the UE, beginning at a start of the scheduled transmission window until the designated transmission time.

3. The UE of claim **1**, the MAC layer circuitry further arranged to perform operations to:

perform a contention channel access technique to obtain access to the wireless channel during the resource contention window, the contention channel access technique including obtaining a backoff time for contention during the resource contention window, and waiting for the backoff time to expire, prior to sending the request message during the resource contention window.

4. The UE of claim **1**, the MAC layer circuitry further arranged to perform operations to:

resend the request message via the PHY circuitry during the resource contention window in response to the request message not being acknowledged by the UE within a period of time.

5. The UE of claim **1**, wherein the resource contention window and the scheduled transmission window are allocated for peer-to-peer communications among devices according to a standard from an IEEE 802.11 standards family, or for machine-to-machine communications among devices according to a standard from an IEEE 802.16 standards family.

6. The UE of claim **1**, wherein the resource contention window and the scheduled transmission window occur in a zone allocated for the device-to-device communications in a wireless channel, and wherein a size of the resource contention window relative to the scheduled transmission window is configured to change based on characteristics of one or more data transmissions requested during the resource contention window.

7. A method performed by a dual-mode user equipment (UE) for facilitating device-to-device communications with a receiving wireless communications device, the dual-mode UE configured for communications with a carrier-based network in addition to the device-to-device communications, and the method comprising:

accessing a wireless channel using a random access contention channel access technique, within a resource contention window allocated for scheduling device-to-device communications in a wireless channel, the resource contention window occurring during a device-to-device communications period indicated by a carrier-based network, the device-to-device communications period allocated from a portion of an uplink segment of an LTE or LTE-A frame;

transmitting a request message to the receiving communications device, within the resource contention window, to obtain a designated transmission time for a device-to-device data transmission, the designated transmission time occurring within a first portion of a scheduled transmission window within the device-to-device portion of the uplink segment and determined by the receiving communications device and communicated to the dual-mode UE in a response message, wherein other devices may transmit in a second portion of the scheduled transmission window;

conducting the device-to-device data transmission from the UE to the receiving communications device at the designated transmission time; and

refraining from transmitting during the second portion of the scheduled transmission window.

8. The method of claim **7**, further comprising:

conducting a sleep mode within the scheduled transmission window; and

interrupting the sleep mode within the scheduled transmission window to conduct the device-to-device data transmission.

9. The method of claim **7**, wherein the contention access technique includes obtaining a backoff time for contention within the resource contention window, and waiting for the backoff time to expire, prior to transmitting the request message within the resource contention window.

10. User Equipment (UE) comprising:

a transceiver comprising circuitry including physical layer circuitry and media-access control layer (MAC) layer circuitry, the circuitry arranged to establish device to device channel access in a wireless communication medium, the media-access control (MAC) layer circuitry configured to:

receive via the physical layer circuitry, a request message, from a transmitting device, to conduct a data transmission during a resource contention window, the resource contention window being allocated from a device-to-device portion of an uplink segment of an LTE or LTE-A frame, for wireless device-to-device communications, the request message indicating a size for a data transmission and being sent from the transmitting device on the wireless communication medium using a random access contention-based technique;

determine a transmission time for the data transmission, the transmission time occurring within a first portion of

a scheduled transmission window of the device-to-device portion of the uplink segment allocated for the wireless device-to-device communications, and wherein other devices may transmit in a second portion of the scheduled transmission window;

send via the physical layer circuitry, a response to the request message, the response confirming the request message and designating the transmission time; and

receive the data transmission from the transmitting device via the physical layer circuitry from the wireless communication medium at the transmission time, during the scheduled transmission window allocated for the wireless device-to-device communications;

refraining from transmitting during the second portion of the scheduled transmission window; and

wherein the resource contention window and the scheduled transmission window are allocated for the wireless device-to-device communications according to timing designated by a network controlled by an evolved Node B (eNodeB).

11. The user equipment of claim **10**, the MAC layer circuitry further arranged to perform operations to:

maintain, from the transmitting device, a low-power mode beginning at a start of the scheduled transmission window until the transmission time.

12. The user equipment of claim **10**, the MAC layer circuitry further arranged to perform operations to:

obtain a backoff time for contention during the resource contention window, and waiting for the backoff time to expire, prior to sending the response to the request message, wherein the response to the request message is sent during the resource contention window.

13. The user equipment of claim **10**, the MAC layer circuitry further arranged to perform operations to:

provide an acknowledgement of data received from the transmitting device in response to the data transmission.

14. A method for facilitating device-to-device communications with a transmitting device, comprising:

processing a request message to conduct a data transmission during a resource contention window and obtain a time of transmission for the data transmission, the request message indicating a size for the data transmission and being sent from the transmitting device over a wireless medium using a random access contention channel access technique to access the wireless medium during a resource contention window of a device-to-device portion of an uplink segment of an LTE or LTE-A frame;

determining a time for the data transmission, the transmission time designated within a first portion of a scheduled transmission window of the device-to-device portion of the uplink segment, wherein other devices may transmit in a second portion of the scheduled transmission window;

transmitting a response to the request message, the response confirming the request message and designating the transmission time;

processing the data transmission from the transmitting device on the wireless medium received at the determined time during the scheduled transmission window;

refraining from transmitting during the second portion of the scheduled transmission window; and

wherein the scheduled transmission window and the resource contention window are designated by an evolved Node B (eNodeB) for performance of wireless device-to-device communications on the wireless medium.

15. The method of claim **14**, further comprising:

conducting a sleep mode during the scheduled transmission window; and

interrupting the sleep mode during the scheduled transmission window to conduct the data transmission.

16. The method of claim **14**, wherein the response to the request message is transmitted via the wireless medium in connection with the contention channel access technique, wherein the contention channel access technique includes obtaining a backoff time for contention during the resource contention window, and waiting for the backoff time to expire, prior to transmitting the response to the request message during the resource contention window.

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